

Early work load tests for evaluation of long-term prognosis of acute myocardial infarction

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Exercise tests performed 3 and 9 weeks after acute myocardial infarction in 205 patients were found to give prognostic information on the survival during a follow-up period of 2 to 5 years. The appearance of tachycardia, major ventricular arrhythmias, or anginal complaints during these early exercise tests was thus accompanied by a significantly increased mortality during the observation period. Ventricular arrhythmias disclosed by exercise proved to be of higher prognostic significance than those recorded at rest on the same occasions. The usefulness of early exercise tests in the evaluation of the response to antiarrhythmic treatment after acute myocardial infarction as well as of the prognostic importance of the effects was documented in a smaller series of patients.

Modern coronary care units (CCU) have led to an appreciable reduction of the early mortality in acute myocardial infarction. This improvement is probably mainly the result of the early detection and treatment of arrhythmias. The mortality during the first years after an acute myocardial infarction, however, remains high and has been found to be correlated with ventricular arrhythmias observed on the resting electrocardiogram recorded at discharge from hospital (Lown and Wolf, 1971; Helmers, 1973; Coronary Drug Project Research Group, 1973). In a previous investigation (Ericsson *et al.*, 1973), we have drawn attention to the value of an early post-acute myocardial infarction exercise test to disclose limiting factors and arrhythmias. The present investigation, which is an extended retrospective study, aims at evaluating the results from these early exercise tests in relation to the long-term prognosis as well as the potential value of these tests in the therapeutic management of the patients, with special reference to arrhythmias.

Subjects

Studies were made on 205 patients in whom it had been possible to perform an early exercise test after an acute myocardial infarction. There were 183 men and 22 women with a mean age of 59 ± 9 years (mean ± 1 SD) for the entire group.

In accordance with our previous study (Ericsson

et al., 1973) a diagnosis of acute myocardial infarction was based on the fulfilment of at least two of the following criteria:

(1) Acute central chest pain lasting for at least 30 minutes.

(2) Rise in aspartate aminotransferase (SGOT), with values higher than those for alanine aminotransferase, or lactic dehydrogenase iso-enzyme, which in a few cases was diagnostic when only moderate rises in aspartate aminotransferase were seen.

(3) Electrocardiographic pattern compatible with acute myocardial infarction. In the diagnosis of true posterior infarcts a vector-electrocardiogram (Frank-system) was used.

The location of the infarction was antero-septal or anterolateral in 99 cases, inferior in 57, and posterior in 10 cases. In 32 cases multiple infarcts were diagnosed whereas in 7 patients no exact location could be obtained.

The present infarction was considered to be the first acute myocardial infarct in 168 of the patients. Thirty patients had had one acute myocardial infarct previously and 7 patients had had two or more infarcts.

The patients were treated in the CCU at Danderyd Hospital during the period April 1970 to March 1973, during which time 430 patients were treated for acute myocardial infarction (Fig. 1). The hospital mortality was 20 per cent (84 patients). There were 172 patients aged more than 65 years

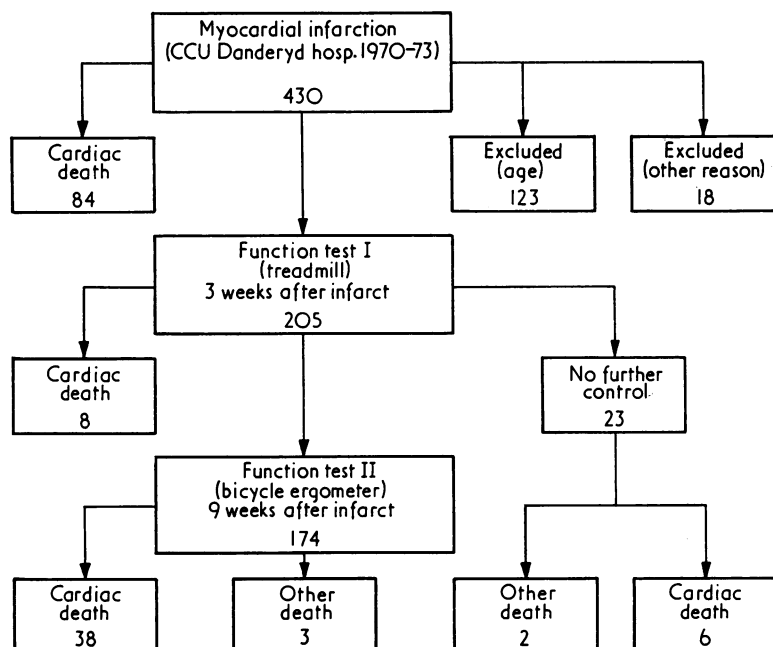


Fig. 1 Patient group subjected to exercise testing 3 and 9 weeks, respectively, after an acute myocardial infarct and groups of patients excluded and deceased.

and in 123 of these cases no early work-load test was performed mainly because of lack of resources in the laboratory at the start of the study and in some cases because of general disability. A further 18 patients were excluded from the early exercise test because of transfer to other departments (12) or other complicating disease (6).

On the remaining 205 patients a treadmill test was performed 3 weeks after the onset of the acute illness after a period of increasing mobilisation under the guidance of a physiotherapist. In 174 patients a further outpatient exercise test on a bicycle ergometer was performed 9 weeks after the acute myocardial infarction. Eight patients died before this second test and another 23 patients could not be re-evaluated for other reasons (reinfarction 9, severe heart failure 3, severe angina pectoris 1, bronchial asthma 2, acute gall-bladder disease 1, acute infection 1, general weakness 1, unknown reasons 3, and 2 patients had moved). In this group of 23 patients who could not be re-evaluated, 8 died of whom 6 were in acute cardiac disease. This mortality corresponds to that of the remaining patients who were available for re-evaluation. At follow-up of the entire patient group in March 1975, 2 to 5 years after the acute myocardial infarction, 52 of the 205 patients (25%) had died of their cardiac illness (Fig. 2). The two-year total mortality amounted to 24 per cent.

Methods

TREADMILL TEST

The first exercise test 3 weeks after the acute myocardial infarct was performed on a treadmill (Collins, P 2000). This particular type of exercise

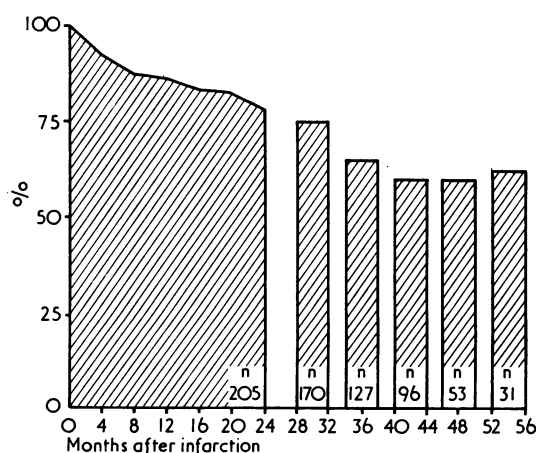


Fig. 2 Percentage survival at various time intervals after discharge from coronary care unit (CCU) in 205 patients taking part in first exercise test. n, number of patients followed to different time intervals.

was considered most suitable in testing the patient's ability to return to the activities of daily life. The procedure has been thoroughly described in a previous paper (Ericsson *et al.*, 1973). The walking speed was accordingly standardised to 0.5 m/s and the inclination angle adjusted to the body-weight so as to obtain an initial load of 100 or 200 kpm/min corresponding to 16 or 33 W, respectively. If possible, the load was later increased by another 16 or 33 W every 6 minutes through a further increase of the inclination angle. The treadmill test was continuously supervised by a physician and was interrupted at the appearance of anginal pain (42 patients), dyspnoea (10 patients), or alarming electrocardiographic abnormalities, notably ventricular arrhythmias (29 patients). In 7 patients exercise was interrupted because of general fatigue and in another 16 patients when the heart rate reached 140 beats/min. In the remaining 101 patients caution was the main reason for ending the exercise test with particular regard to earlier arrhythmias or the general condition of the patient.

BICYCLE TEST

The second exercise test 9 weeks after infarction was performed on an electrically braked bicycle ergometer according to the routine procedure of exercise testing at the hospital. The initial load was 33 W for 6 minutes with a stepwise increase of 33 W every 6 minutes until the test was interrupted for the same reason as the treadmill walking, i.e. anginal pain (36), dyspnoea (7), electrocardiographic abnormalities (32), fatigue (6), heart rate > 140 beats/min (38), and caution (55 patients).

ELECTROCARDIOGRAM RECORDING

The electrocardiogram was recorded during supine rest for 2 minutes before each function test with a further recording during 8 minutes in a standing position before the second function test on the bicycle ergometer. During exercise the electrocardiogram was registered continuously as well as during the 10 minutes rest after break. The re-

cordings of the resting electrocardiogram comprised conventional extremity leads and 6 praecordial leads with the reference electrode on the right arm (CR leads). During exercise the reference electrode was positioned on the forehead (CH leads). A direct writing ink-jet recorder (Mingograph 81, Siemens-Eléma) was used.

Results

The mortality during the follow-up time of 2 to 5 years has been correlated with certain clinical data from the acute illness and ventricular arrhythmias observed during the stay in the coronary care unit, as well as those seen during the exercise test 3 and 9 weeks after the acute myocardial infarction (Fig. 3). The ventricular arrhythmias were defined as multifocal, paired and/or ≥ 5 ventricular ectopic beats (VEB)/min. We have also examined exercise-induced tachycardia, angina pectoris, and dyspnoea in relation to prognosis (Fig. 4).

CLINICAL DATA (Table)

When comparing the 57 patients who died during the observation time with the 142 survivors, there were no differences regarding age, cardiac size, and maximum enzyme levels (aspartate aminotransferase) as observed in the coronary care unit. In contrast, there were more deaths among those patients who had had a previous infarction as compared with those with a first infarction (17/37 and 40/168, respectively); this difference is probably significant ($P < 0.05$).

VENTRICULAR ARRHYTHMIAS (Fig. 3)

Coronary care unit stay

During the coronary care unit stay 109 of 197 continuously monitored patients (59%) had ventricular arrhythmias. Of these 109 patients, 23 (21%) also had ventricular arrhythmias during the treadmill test 3 weeks after the acute event as compared with 10/88 (11%) of those without ventricular arrhythmia in the coronary care unit ($P < 0.05$). In these two groups with arrhythmias at the time of the first exercise test 10 and 2 patients, respectively, were on antiarrhythmic therapy.

Resting electrocardiogram

Six patients (3%) had ventricular arrhythmias at the time of the routine resting electrocardiogram 3 weeks after the acute myocardial infarction. During the observation time one of these patients died as compared with 56/199 without ventricular arrhythmias on this recording (n.s.). Nineteen patients (11%) showed ventricular arrhythmias on

Table Some clinical data from period in coronary care unit and number of infarctions correlated to follow-up mortality

	Dead at follow-up	Alive at follow-up
Age at infarction (y)	60 \pm 9	59 \pm 9
Serum aspartate aminotransferase (max), (μ katal)	3.5 \pm 2.6	2.9 \pm 2.3
Heart volume (ml per m ²)	567 \pm 103	483 \pm 136
First infarction (no. of patients)	40	128
Reinfarction (no. of patients)	17	20

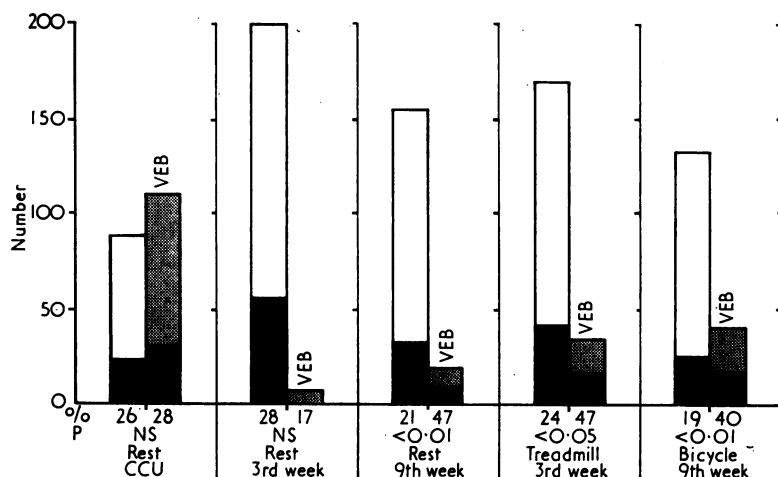


Fig. 3 Mortality in patients with and without ventricular ectopic beats (VEB) during CCU care or at follow-up control 3 and 9 weeks after acute myocardial infarct. The solid black parts of the total bars represent number of patients dying during follow-up period within respective patient groups, with the mortality percentage presented below. P values indicate significance levels for differences in mortality as calculated from χ^2 analyses.

the resting electrocardiogram taken at the time of the second exercise test 9 weeks after the acute myocardial infarction. Nine of these patients died during the follow-up time in comparison with 32/155 of the patients without ventricular arrhythmias, giving a significantly lower mortality in the latter group ($P < 0.01$).

Exercise electrocardiogram

At the treadmill test 3 weeks after the acute myocardial infarction, ventricular arrhythmia was seen in 34 patients (17%). Fourteen of these were on antiarrhythmic therapy as compared with 41 of 171 patients without ventricular arrhythmias. Furthermore, 135 patients were treated for heart failure with digitalis and diuretics. The mortality for

patients with ventricular arrhythmia was 16/34 in comparison with 41/171 of those without ventricular arrhythmias at this initial exercise test. The difference is probably significant ($P < 0.05$).

Antiarrhythmic therapy was introduced in 12 of 17 patients with ventricular arrhythmias at the time of the first exercise test and altered in another 5 patients. Thirteen of these patients were given procainamide 0.5 g 4 times daily. On a repeated exercise test ventricular arrhythmias persisted in spite of altered therapy in 5 patients. Four of these 5 patients subsequently died as compared with 2 of 12 who became free from ventricular arrhythmias.

Ventricular arrhythmias were seen during the exercise test 9 weeks after the acute myocardial infarct in 40 of the 174 (23%) patients. During the

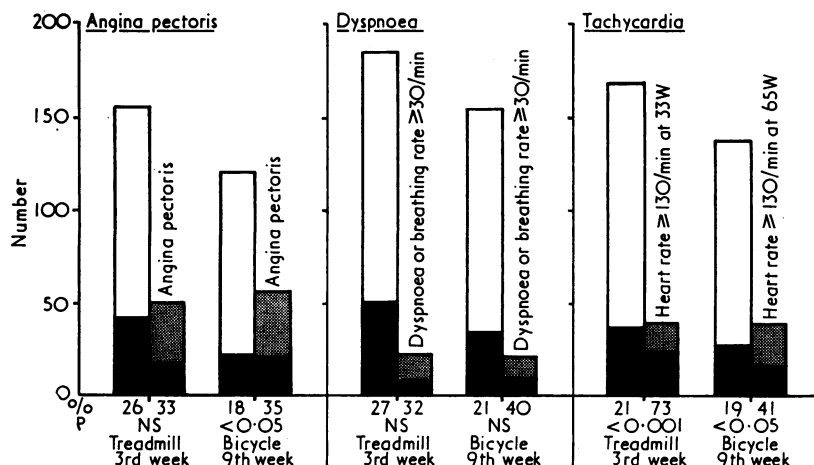


Fig. 4 Mortality in patients with and without angina pectoris, dyspnoea, and tachycardia, respectively, in association with exercise test 3 and 9 weeks after acute myocardial infarction. Symbols as in Fig. 3.

follow-up time 16 of these died as compared with 25 of 134 without arrhythmias, which implies a significantly higher mortality in those with ventricular arrhythmias at this stage ($P < 0.01$).

TACHYCARDIA (Fig. 4)

At the exercise test 3 weeks after the acute myocardial infarct tachycardia, defined as heart rate ≥ 130 /min at a workload of 33 W, was seen in 30 patients. Twenty-two of these died during the follow-up period as compared with 35 of 167 without this increase in heart rate. This difference is highly significant ($P < 0.001$).

At the exercise test 9 weeks after the acute myocardial infarct 37 patients had a corresponding tachycardia at a load of 65 W. In this group 15 patients subsequently died as compared with 26 of 137 of the remaining patients ($P < 0.05$).

Maximum heart rates were on an average higher at the second exercise test as compared with the first, 126 ± 18 (mean \pm SD) and 117 ± 15 beats/min, respectively. The mean values for the corresponding final loads were 78 ± 24 W and 45 ± 19 W, respectively.

ANGINA PECTORIS (Fig. 4)

Angina pectoris occurring at the time of the first exercise test 3 weeks after the acute myocardial infarct did not imply a raised mortality during the follow-up time. At this test 49 patients developed angina and 16 died as compared with 41 of 156 without angina. In contrast a certain increase in mortality was seen among those patients who developed angina pectoris at the second exercise test 9 weeks after the acute myocardial infarct. Thus 19 of 55 patients with angina pectoris at this test died in comparison to 22 of 119 without.

DYSPNOEA (Fig. 4)

Dyspnoea, defined as difficulty in breathing and/or a respiratory rate ≥ 30 /min, was seen in 22 patients during the treadmill test and 20 patients during the second exercise test on the bicycle ergometer. There was no increase in mortality in either group with dyspnoea during the follow-up.

COMPLICATIONS

One patient developed prolonged ventricular tachycardia after the bicycle ergometer test and was successfully electroconverted. No other major arrhythmias or complications occurred during these tests.

Discussion

A certain selection of patients has been made in the

present study (Fig. 1), but the results obtained seem to agree well with previous studies as regards survival after acute myocardial infarction (e.g. Shanoff *et al.*, 1966; Helmers, 1973). The relative merits of long-term recording and exercise tests in the detection of severe cardiac arrhythmias after acute myocardial infarction have been discussed by several authors (Kosowsky *et al.*, 1971; Crawford *et al.*, 1974; Kentala *et al.*, 1975; Rehnqvist, 1976; Ryan *et al.*, 1975). The information obtained from prolonged supervision and exercise tests, respectively, is clearly in part dependent on the duration of the registration and the design of the exercise test. Thus Kosowsky *et al.* (1971) suggested that one is more likely to detect ventricular arrhythmias during a short exercise test as compared with a monitoring period of 2 hours. In contrast, Ryan *et al.* (1975) found that a 24-hour ambulatory recording period indicated twice as many instances of coupled ventricular ectopic beats and periods of ventricular tachycardia as exercise testing in patients with coronary artery disease. The same authors, however, suggest that these different methods probably disclose types of arrhythmias which differ in respect of both aetiology and prognostic significance. Crawford *et al.* (1974) found that a 10-hour continuous recording showed more serious arrhythmias than a treadmill exercise test but they still consider that there is a need for an evaluation of the prognostic value of exercise tests. In our opinion, exercise tests carry the advantage of standardised conditions of investigation as well as supervision of the patient. It has moreover been suggested by Ryan *et al.* (1975) that those arrhythmias which are frequent during long-term monitoring also appear during exercise testing.

In accordance with our previous investigation (Ericsson *et al.*, 1973) we again found in this extended study that the occurrence of ventricular arrhythmias during the stay in coronary care unit did not affect the long-term prognosis. On the other hand, confirmation was obtained that the occurrence of ventricular arrhythmias seen during early exercise testing was associated with a significantly raised incidence of sudden death during the years after an acute myocardial infarct. This observation is in contrast to the results recently reported by Kentala *et al.* (1975)—who by stepwise multiple discriminant analysis found the prognostic significance of ventricular arrhythmias during early exercise tests to be poor. The importance of ventricular arrhythmias as an independent risk factor after acute myocardial infarction has been stressed by Kotler *et al.* (1973) who based their conclusions on intermittent long-term recording during ordinary daily activities. Our patient group is too limited in

number to allow for a closer analysis of the prognostic importance of different forms of ventricular arrhythmias. Kotler *et al.* (1973) have, however, observed that ventricular parasystole after acute myocardial infarction does not carry a worsened prognosis as regards sudden death. No major investigations of the value of antiarrhythmic therapy in patients surviving an acute myocardial infarct with persistent ventricular irritability exist today. Ryan *et al.* (1975) have pointed to the difficulties in the medical management of these arrhythmias. Kotler *et al.* (1973) also question the possibilities of preventing sudden deaths during the first years after acute myocardial infarct. In this limited patient material where it was possible to observe the antiarrhythmic effect by repeated exercise testing, a lower mortality was found among patients who became free from arrhythmias than those who remained arrhythmic (2/12 compared to 4/5). Whether this finding is a result of therapy or whether it merely reflects that a severely damaged myocardium fails to respond to therapy, cannot be answered without more extensive studies.

Our present results also show that a pronounced increase in heart rates during early exercise tests after acute myocardial infarct carries a poor prognosis. It is probable that these raised heart rates reflect a poor stroke volume caused by impaired myocardial function. Similarly, decreased myocardial function after an acute myocardial infarct probably also accounts for the unfavourable prognosis associated with a poor systolic pressure rise during exercise in these patients (Kentala *et al.*, 1975). Tachycardia might sometimes merely have been an expression of a raised sympathetic drive, factor which, however, also may affect the prognosis.

Our observation of a worsened prognosis associated with angina pectoris developing during early exercise tests after an acute myocardial infarct suggests that the degree of coronary insufficiency has its obvious prognostic role apart from ventricular arrhythmia and myocardial insufficiency. We refrained from an evaluation of the degree of coronary insufficiency on the electrocardiographic pattern because of the accepted difficulties of evaluating ST changes after previous acute myocardial infarction and also as the changes seen may be influenced by cardiotropic therapy.

Conclusions

We found that routine exercise tests 3 weeks and 9 weeks after an acute myocardial infarct give

valuable prognostic information using the following measures: substantially increased heart rates, angina pectoris, and major ventricular arrhythmias. The exercise tests disclose a larger risk group than an ordinary resting electrocardiogram recorded on the same occasion. We consider that these early exercise tests, owing to the possibilities of standardisation and supervision, are a useful method for investigating the therapeutic and physical exercise management of these patients. Further studies are, however, required for the evaluation of the effect of antiarrhythmic therapy as well as treatment aimed at those symptoms found to be related to a worsened prognosis in these patients.

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